

 Environment Canada Environnement Canada
1035060D DEST PVM EXCH COPY 03
SD 13 F66
VOL ISS 82-83
FOREST PEST MANAGEMENT INSTITUTE (C
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PROGRAM REVIEW

1982-83

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1982 ~ 83

**Forest Pest Management Institute
Canadian Forestry Service
Environment Canada**

1983

© Minister of Supply and Services Canada, 1983

ISSN: 0820-7461

ISBN: 0-662-12935-0

Cat. No.: Fo 41-5/1983E

Additional copies of this publication are available
from:

Forest Pest Management Institute
Canadian Forestry Service
P.O. Box 490
Sault Ste. Marie, Ontario
P6A 5M7

Cette publication est aussi disponible en français
sous le titre: *Revue des programmes, Institut
pour la repression des ravageurs forestiers, 1982-83.*

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THE CANADIAN FORESTRY SERVICE

ENVIRONMENT CANADA

The Canadian Forestry Service (CFS) is the principal source of federal expertise in forestry. Its general objective is to promote the wise management and use of Canada's forest resource for the economic, social, and environmental benefit of Canadians.

The following are the main functions of the CFS:

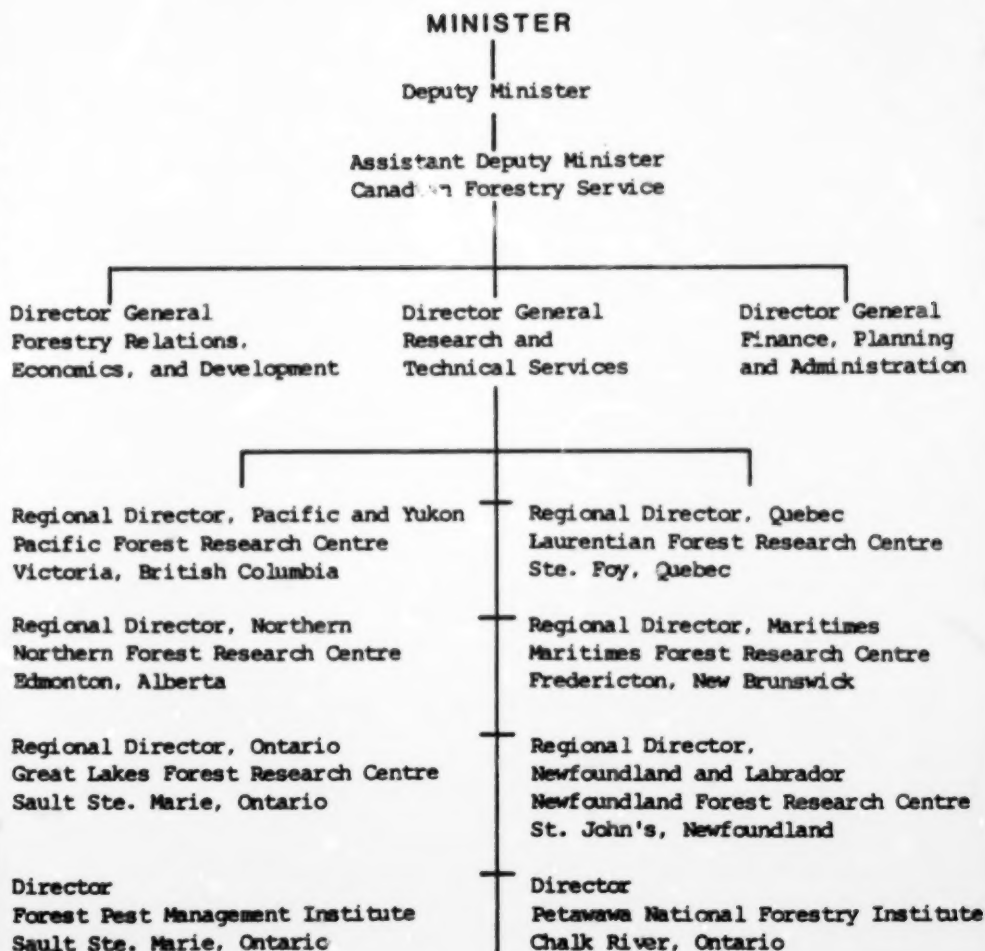
1. Providing coordinated federal policies to promote forest industry development and better resource management;
2. Providing scientific and technical leadership through research and development;
3. Providing and analyzing national and international information and statistics as a basis for policy;
4. Aiding in developing and certifying codes and standards of product performance;
5. Protecting Canada's forests from foreign pests;
6. Supporting provincial forest renewal programs to ensure permanent viability of the forest resource;
7. Fostering the potential use of the forest resource for energy; and,
8. Contributing to the environmental objectives of the Department of the Environment.

A number of federal agencies are involved in forestry programs, and a Federal Forestry Sector Strategy Committee has been established to coordinate federal forestry activities. The CFS has been designated the lead agency.

In September, 1982, the Canadian Forestry Service assumed responsibility for regional economic development from a forestry standpoint. In this context the Service is required to negotiate federal-provincial forest renewal agreements of intensive forest management practices to meet the objective of the federal forest sector strategy. As a result, the CFS is also involved in the development of economic profiles and studies to identify regional and national needs, and development opportunities.

The Canadian Forestry Service is composed of a headquarters unit, six forest research centres, and two national institutes. The forest research centres are responsive to regional priorities and maintain close liaison with the respective provincial government forestry departments. They also participate in, and frequently lead, national programs. The national institutes provide the focus for programs of national scope. The headquarters unit comprises three directorates - Research and Technical Services, which plans, directs and coordinates the research and development programs and technical services of the CFS, Forestry Relations, Economics, and Development, which handles forestry relations with university, industry and other governments, economic analyses, as well as the coordination of the forestry development and employment stimulation programs; and Finance, Planning, and Administration, which manages the support services of the CFS in planning and program evaluation, finance, administration, and human resources management.

ENVIRONMENT CANADA



SERVICE CANADIEN DES FORÊTS

ENVIRONNEMENT CANADA

Le Service canadien des forêts (SCF) réunit la majorité des spécialistes fédéraux en foresterie. Son objectif général est de promouvoir l'aménagement et l'utilisation judicieuse des ressources forestières du Canada pour le plus grand bien économique, social et environnemental des Canadiens.

Voici les principales fonctions du SCF:

1. Fournir des politiques fédérales coordonnées afin de favoriser l'expansion de l'industrie forestière et l'amélioration de la gestion des ressources;
2. Fournir une orientation scientifique et technique par la recherche et le développement;
3. Fournir et analyser l'information et les statistiques nationales et internationales qui serviront de base aux politiques;
4. Aider à la mise au point et à la certification des codes et des normes en matière de performance des produits;
5. Protéger les forêts canadiennes en luttant contre les ravageurs étrangers;
6. Appuyer les programmes provinciaux de régénération forestière afin d'assurer la viabilité permanente des ressources forestières;
7. Parrainer l'utilisation éventuelle des ressources forestières pour la production d'énergie; et
8. Adhérer aux objectifs environnementaux du ministère de l'Environnement.

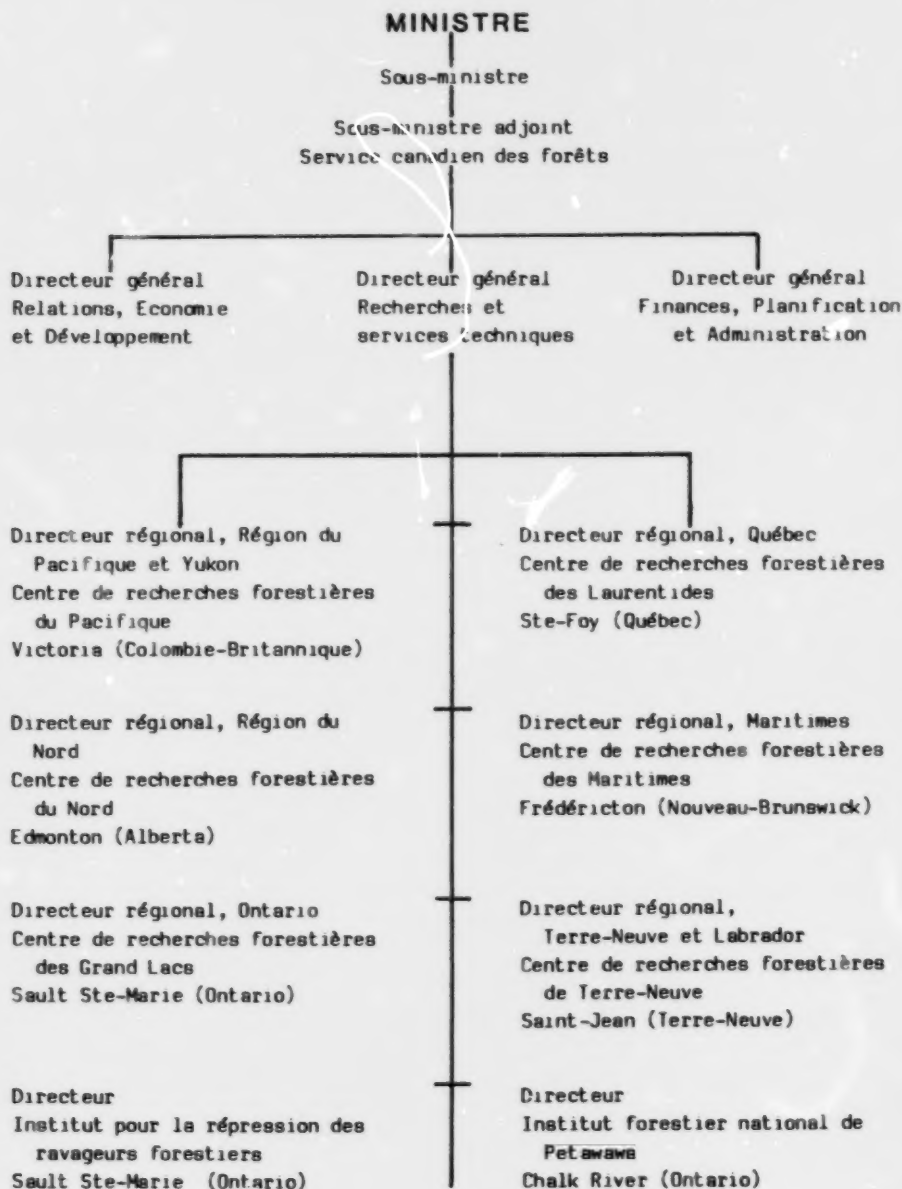
Depuis septembre 1982, le SCF assume la responsabilité du développement économique régional dans le domaine forestier. À ce titre, il doit conclure des ententes fédérales-provinciales, relatives à la régénération forestière, sur des méthodes de gestion intensive des forêts afin d'atteindre les objectifs de la stratégie forestière du Canada. Le SCF doit conséquemment participer à la mise au point de profils et d'études économiques afin de cerner les besoins sur les

plan régional et national, de même qu'aux possibilités de développement.

Le SCF comprend une administration centrale, six centres de recherche forestière et deux instituts nationaux. Les centres de recherche forestière doivent répondre aux impératifs régionaux et entretenir une liaison étroite avec les ministères provinciaux des Forêts. Ils participent également à des programmes nationaux dont ils assument fréquemment la direction. Les instituts nationaux sont les foyers des programmes d'envergure nationale.

L'Administration centrale comprend trois directions générales: Recherche et Services techniques, dont le rôle consiste à planifier, diriger et coordonner les programmes de recherche et développement ainsi que les services techniques du SCF; Relations, Économie et Développement, qui s'occupe des relations forestières avec les universités, l'industrie et les autres gouvernements, d'analyses économiques ainsi que de la coordination des programmes de développement forestier et de création d'emplois; et Finances, Planification et Administration, qui dirige les services de soutien du SCF dans la planification, l'évaluation des programmes, les finances, l'administration et la gestion du personnel.

MINISTÈRE DE L'ENVIRONNEMENT



Director's Foreword

The Forest Pest Management Institute (FPMI) was formed in 1977 through amalgamation of the former Insect Pathology Research Institute (IPRI), Sault Ste. Marie, and the former Chemical Control Research Institute (CCRI), Ottawa. Transfer of the latter to Sault Ste. Marie was completed by the fall of 1979. The total staff of 87 person-years is accommodated in the former IPRI building and in space modified to meet FPMI requirements in the Great Lakes Forest Research Centre facility.

This amalgamation brought under one direction extensive expertise within the Canadian Forestry Service (CFS) in biological control agents, chemical pesticides, application technology, and environmental concerns. It has provided a unique opportunity to develop a Research and Development (R & D) program that can provide forest managers with effective pest management strategies in a more comprehensive and coordinated manner than has been possible in the past.

The Forest Pest Management Institute shares the overall objective of the Canadian Forestry Service: "To promote the wise management and use of Canada's forest resources for the economic, social, and environmental benefit of Canadians." The Institute's R & D program is devoted exclusively to the development of efficacious, environmentally acceptable pest management strategies that will assist forest managers to achieve forest management objectives.

As a National Institute, FPMI's research interests and mandate transcend regional boundaries. It brings together special expertise, research equipment, and facilities that would be difficult to duplicate in regional research centres within the Canadian Forestry Service. Because of this, the Institute's program adds support and depth to pest management programs undertaken by CFS regional forest research centres and, hence, is aware of pest management problems facing provincial forest managers. A cooperative approach to the solution of mutual problems is advantageous and, whenever possible, is practiced by the Institute and regional elements of the CFS and provincial forest authorities.

Research at FPMI is carried out within two national programs:

Improved Forest Management. If Canada's share of the foreign market in wood and wood products is to be maintained or increased in the years to come, forestry in the 1980s must be committed to a massive program of intensive forest management, including the return to

productivity of a large and growing backlog of inadequately regenerated cutover. This commitment requires large investments in regeneration and stand tending, both to increase forest production and to enhance the social and aesthetic values of our forest resources.

It makes little sense, however, to invest heavily in these areas unless we are prepared to carry out effective pest management strategies against important forest insects and competing vegetation. Losses to these agents can be limited to acceptable levels that will allow forest managers to capitalize on their investments and to achieve desired forest management goals. A large portion of the FPPI research program, therefore, is devoted to Biological Control Research, which attempts to develop effective, naturally occurring insect pathogens (bacteria, viruses, fungi, protozoa) for forestry use; to Physiological and Genetic Mechanisms (insect growth regulators, pheromones, and genetic mechanisms); to Chemical Control Research including the toxicology and screening of chemical insecticides and field testing of the efficacy of both chemical and biological insecticides; and to Application Technology, which develops methods for delivering control agents to the target in the most effective and efficient manner. The Institute has recently become involved in Herbicides Research because more intensive forest management in Canada has increased the need to control competing vegetation.

Environmental and Amenity Forestry. The intelligent use of pest control products demands that their use impose a minimal risk to the environment and to public health. Although the effects on public health lie outside the mandate of FPPI and are monitored by appropriate federal and provincial health agencies, the Institute is heavily involved in research on Environmental Impact and Chemical Accountability of pesticides. Such research is required to determine the effects of pesticides on nontarget organisms in the forest environment and their persistence, dynamic cycling, and ultimate fate following their introduction into the forest ecosystem.

These thrusts in Improved Forest Management and Environmental and Amenity Forestry are supported by a Complementary Research Project, which provides fundamental research in cell biology, tissue culture, serology, and computer applications. Technical services in insect and pathogen production, and plant and animal production are provided by a Complementary Services Project.

Data generated within the total Institute R & D program are essential for the development of new and improved pest control products for forestry use and for the development of strategies for their operational use. In addition, Institute research provides data for registration packages of pest control products for forestry use and upon which effective yet environmentally benign use patterns are developed and promulgated under terms of the Pest Control Products Act.

G.W. Green
Director

1 April 1983



**IMPROVED
FOREST
MANAGEMENT**



Biological Control Research

Forest insect pests live in association with a wide variety of organisms that, in one way or another, can reduce the insects' chance of survival by adversely affecting their mobility, viability, and reproductive success. These organisms include bacteria, viruses, fungi, and protozoa. To increase the options available to the forest manager for the control of economically important insect pests, biological control research at the Institute is directed towards determining the conditions under which the naturally occurring insect pathogens can be used to prevent insect outbreaks, or to reduce them once they have occurred. When these conditions have been identified, strategies can be developed for the use of these entomopathogenic organisms, either by themselves, or in concert with other methods, including chemical control.

Institute research into biological control presently concentrates on three main areas; the identification of insect-specific pathogens for control use, the elucidation of the conditions under which these organisms exert their effect on naturally occurring populations, and the development of use patterns and strategies for their effective use. These projects investigate naturally occurring host-pathogen interactions (for fungi and microsporidia), develop data necessary to support petitions for registration of certain viruses, and improve application strategies for registered agents. Research into a particular organism can overlap these categories in terms of understanding its natural occurrence and effectiveness, and developing it for use.

FP-1

BACTERIAL PATHOGENS

PROJECT LEADER:

P.G. Fast

SUPPORT STAFF:

R.E. Milne

OBJECTIVES: To enhance the effectiveness of *Bacillus thuringiensis* and related bacterial pathogens for use in the control of forest insects in Canada.

ACHIEVEMENTS: Previous work in this project has shown that the toxicity of *Bacillus thuringiensis* (*B.t.*) resides in the parasporal crystal produced when the bacterium sporulates. The toxin appears to cause loss of permeability control in the cell surface membranes. Cell damage appears to be extensive before feeding inhibition is observed.

The last three larval instars of spruce budworm are all equally susceptible to *B.t.* when it is incorporated into the diet. Similar results have been observed in field experiments, leading to the conclusion that the 'window' during which *B.t.* will be effective may be widened to include 5th- and early 6th-instar larvae.

It has been found that the effect of *B.t.* on spruce budworm larvae mortality is dependent on exposure time as well as on dose. An equation has been derived that describes the discrete effects on exposure time in days and dose on mortality.

A study on the effects of droplet size and number was done in cooperation with Dr. A. Sundaram. Probit analysis of the resulting data allowed the influence of droplet size and number to be expressed in an equation. The effect of concentration of *B.t.* in the droplets was much greater than was anticipated from previous bioassays. A technique has been developed for assessing efficacy of spray applications by comparing defoliation predicted on the basis of prespray larval counts with actual defoliation in sprayed plots at the end of larval growth.

PROJECTIONS: During 1983-84, work will concentrate on further isolation and purification of the toxic peptide of the crystal, as well as on validation of the droplet density and size relationships observed in the laboratory through observations from field experiments.

FP-2

FUNGAL PATHOGENS

PROJECT LEADER:

D. Tyrrell

SUPPORT STAFF:

D. Perry

M. Welton

K. Humphries

OBJECTIVES *To develop methods and procedures for the use of Entomophthora spp. and other fungi in the management of forest insects in Canada.*

ACHIEVEMENTS Since the 1950s, this project has made substantial contributions to the understanding of entomopathogenic fungi with a view to defining conditions under which they can be used as effective control agents. Methods for propagating fungi in the laboratory and studying their mode of action on pest insects arose from early investigations of basic biology and nutritional requirements.

Induced maturation and germination of spores of one species were achieved for the first time. Growth and development were studied to determine optimal stages for infection of field populations, and to develop methods for mass producing these stages. Incidence and development of fungal infection were monitored in field populations to determine the normal course and spread of infection, susceptible stages of the budworm, and distribution of the various fungal stages in the environment.

The kinetics of resting spore germination of *Zoophthora radicans* at different temperatures and pH levels have been determined. Bioassays of known spray volumes and conidial doses on small trees have been started. Field trials of *Z. radicans* and *Entomophthora egressa* on caged trees in both Newfoundland and Ontario achieved

60% or more mortality against 4th-, 5th-, and 6th-instar budworm. Another field study was initiated in Lake Superior Provincial Park to determine causal relationships involved in the development of fungi in spruce budworm populations.

PROJECTIONS Physiological studies will concentrate on determining the conditions necessary for germination, growth, and sporulation of several species with potential for control use. Laboratory and field studies will be aimed at determining both the persistence of fungi in the environment and host-pathogen interactions to find the conditions under which these pathogens can be used effectively.

FP-3

PROTOZOAN PATHOGENS

PROJECT LEADER

G.G. Wilson

SUPPORT STAFF

E.D. Young

OBJECTIVES *To investigate the host-parasite relationships of microsporidia and determine their potential for control of forest insect pests.*

ACHIEVEMENTS Over the past 15 years, this project has made significant progress in elucidating the occurrence and effect of microsporidia in forest insect populations. These parasites were found to have a strong debilitating effect on their hosts: high dosages can result in insect mortality. Microsporidia have been isolated and identified for a number of forest insect pests, including the spruce budworm, forest tent caterpillar, and larch sawfly. Field application of microsporidia to naturally infected spruce budworm populations accelerate the normal development rate of the disease. In spruce budworm, the microsporidia are either ingested or transmitted transovarially from infected females. A microsporidia infecting the larch sawfly has been identified and described.

During 1982-83, tests were conducted to develop a bioassay system for *Nosema fumiiferana* against the spruce

budworm. A bioassay chamber was also developed using a Beem embedding capsule. Laboratory studies established that the pine false webworm is susceptible to the microsporidium *Pleistophora schubergi*. A study of the interactions of spruce budworm and its natural enemy complex (in this case microsporidia) was begun in 1982. A brief description of the microsporidium from white pine weevil was completed and presented at a poster session during the 1982 meeting of the Society of Protozoology.

PROJECTIONS A quantitative bioassay will be developed for the spruce budworm and forest tent caterpillar, which can be used to determine intensity of infection in adults and their offspring and to determine effective levels of infection. Study of the field ecology - population dynamics of the spruce budworm and its microsporidian parasites will continue in order to define the conditions under which microsporidia can contribute to the control of natural populations.

FP-4

VIRAL PATHOGENS

PROJECT LEADER

J.C. Cunningham

SUPPORT STAFF

B.M. Arif	K.W. Brown
W.J. Kaupp	B.E. Cunningham
M. Legris	F.R. Burke

OBJECTIVES *To develop viruses for effective and environmentally acceptable use in the population regulation of important forest insect pests.*

ACHIEVEMENTS Since the 1950s, this project has emphasized the isolation, identification, and investigation of control potential of viruses affecting important forest insect pests including the spruce budworm, Douglas-fir tussock moth, and several sawflies. Efficacy of these viruses has been tested in the laboratory and in small-scale ground and aerial applications. Studies have also been done on spread and mode of action. Biochemical and biophysical analyses are used to determine their specificity and virulence, and to generate the char-

acterization data necessary for registration. In March 1981, the redheaded pine sawfly virus was submitted to Agriculture Canada for registration.

A petition for the registration of a Douglas-fir tussock moth virus (T.M. Biocontrol-1-U.S. product; Vir-tuss - Canadian product) was submitted to Agriculture Canada in 1982. Two viruses, a nuclear polyhedrosis virus (NPV), and a granulosis virus (GV), were tested on western spruce budworm in British Columbia in collaboration with staff at the Pacific Forest Research Centre (PFRC). Virus was applied against the gypsy moth in cooperation with Great Lakes Forest Research Centre (GLFRC) and Ontario Ministry of Natural Resources (OMNR). More efficient methods of laboratory bioassay of foliage and virus suspension have been developed and have proved to be useful in determining the relative pathogenicity of entomopoxvirus isolates, NPVs, and the interaction between different insect pathogens. Dr. B.M. Arif has been successful in learning and implementing recombinant DNA procedures while on career development leave in Cologne, West Germany. Spruce budworm NPV - DNA sequences have been cloned in *E. coli* cells to obtain large amounts for analytical work. The presence of NPV - DNA in chromosomes of cells can also be detected.

PROJECTIONS

Field studies will concentrate on determination of carry-over and spread of viruses applied in 1982 to populations of the Douglas-fir tussock moth, western spruce budworm, and gypsy moth. Epizootiological studies will determine the conditions under which viruses spread and induce epizootics. Biochemical and biophysical characterization of several viruses will continue, and the knowledge and experience gained by Dr. Arif during his development leave will be integrated into the viral biochemistry studies.

FP-14

BIOLOGICAL CONTROL STRATEGIES

PROJECT LEADER

Vacant

SUPPORT STAFF

M.J. Hildebrand

A. Moore

OBJECTIVES *To develop efficacious methods of using biological control agents for the control of forest insect pests.*

ACHIEVEMENTS Research carried out by the CFS showed that the bacterium *Bacillus thuringiensis* var. *kurstaki* (*B.t.*) was toxic to the larvae of the spruce budworm and that it could be considered as a management option for control of this pest. The mode of action of this material and its biological characteristics indicated that the standard aerial application techniques and tactics as developed for chemical insecticides would not be suitable.

In 1978, the Canada-United States Spruce Budworm Program (CANUSA) identified *B.t.* as having high potential for forestry use, but recognized the existence of problems associated with its effective use. Under the CANUSA program, this project has been involved in determining optimal dosages, volumes, and timing of *B.t.* applications, as well as environmental effects on its persistence and toxicity. As a result of this effort, guidelines have been developed for the effective use of registered *B.t.* products.

PROJECTIONS With the departure of the Project Leader to Agriculture Canada, this project's future orientation will be towards identifying critical host - *B.t.* interactions affecting its efficacy. Attention will also be directed towards development of effective *B.t.* use strategies for other forest insect pests.



Physiological & Genetic Mechanisms

A forest insect pest grows and develops through a complex and inter-related series of steps including larval and pupal stages, mating, and reproduction. As knowledge of the physiological and genetic mechanisms associated with such development become better understood, so do the opportunities to identify critical stages that can be manipulated to control economically important insect pests. The Institute program in this area includes research into the physiological mechanisms associated with normal growth and development, the physiological and behavioral aspects of insect mating and reproductive behavior, and the dynamics of insect population genetics. Arising from this research is the strong possibility of manipulating these mechanisms, through chemical or other means, to the detriment of insect survival within a generation, and from one generation to the next.

The research into these areas leads directly to the screening of candidate insect growth regulators and pheromones that have potential for use and the development of methods for their use. Genetic research not only identifies the stages of reproduction susceptible to manipulation, but also contributes significantly to the understanding of population dynamics and how it is affected by the application of control agents, whether they are biological or chemical.

FP-5

INSECT PHEROMONES

PROJECT LEADER

G.G. Grant

SUPPORT STAFF

L.M. MacDonald

D. Frech

OBJECTIVES

To provide the prerequisite basic knowledge on the chemical identification, detection, and behavioral function of insect pheromones to advance their use in the control and monitoring of forest insect pests.

ACHIEVEMENTS

Since 1968, the sex pheromones of several important forest insect pests including the spruce budworm, forest tent caterpillar, the maple leafroller, the western spruce budworm, and *Choristoneura orae* have been identified. The spruce budworm pheromone is now commercially available. A sensitive technique for measuring small quantities of pheromone, developed in a cooperative CANUSA study, has been used to determine the relationship of atmospheric pheromone levels to individual mating behavior. Mating and courtship studies conducted on a number of phycitid, lymantrid and noctuid moths revealed the complexity of the interaction that occurs between male and female moths and have emphasized the role of male sex pheromones in controlling some of these behavioral sequences. Several male sex pheromones have been identified. Detailed courtship studies make it clear that insect mating is a far more intricate process than was realized a decade ago.

During 1982-83, laboratory and field studies resulted in data on lures for several forest pests, such as *Laspeyresia* spp. Further field trials confirmed the compounds attractive for *Croesia semipurpurea*, and two types of lures are now available for this species. A small-scale mating disruption test against *Eucosma gloriola* was successful in terms of both trap catch and damage reductions. Candidate attractive compounds were identified for *Zeiraphera* spp.

PROJECTIONS

During 1983-84, the Project Leader will be on career development leave at the University of Southampton, U.K., to gain expertise in the use of pheromones for the direct control of forest insect pests. Work will

continue on correlation of trap catch to insect density, on confirming or further clarifying attractive compounds for several species, and on small-scale mating disruption tests.

FP-6

INSECT GROWTH REGULATORS

PROJECT LEADER

A. Retnakaran

SUPPORT STAFF

L.F.R. Smith

W. Tomkins

OBJECTIVES *To evaluate and develop the use of insect growth regulators for the management of Canadian forest insect pests.*

ACHIEVEMENTS Beginning in 1968, the project investigated chemosterilants and then insect growth regulators (IGR) for their control potential. A number of moult inhibitors, such as Dimilin, have been screened in laboratory, greenhouse, and small-scale aerial field tests against such pests as the spruce budworm, forest tent caterpillar, and oak leaf-tier; several have shown high potential for control. Companion laboratory studies have established the biological and biochemical mode of action of these compounds.

Laboratory studies have demonstrated that the spruce budworm is less susceptible to Dimilin than the forest tent caterpillar. A model system for studying the action of juvenile hormone analogues, neuropeptide antagonists, and related compounds was developed using the oleander hawk moth as a species in which the last larval instar shows a characteristic color change associated with juvenile hormone titre changes. A study of the feeding behavior of the last three budworm larval instars showed that most of the ingestion occurred in the 6th-instar and that the feeding rate increases exponentially with temperature.

During 1982-83, the use of juvenile hormone analogues to increase virus production was studied in cooperation with other Institute scientists. In another cooper-

ative study, the amaranth diet technique was used to measure feeding deterrence of *B.t.* and subsequent recovery by the larvae; it was found that the feeding inhibition effect could be isolated from mortality effects. Studies were initiated on the biology of the white pine weevil at a field site near Iron Bridge, Ont.

PROJECTIONS

The Project Leader will be on career development leave with the Commonwealth Scientific and Industrial Research Organization (CSIRO), Canberra, Australia, during 1983-84, gaining expertise in the enzymatic pathways of chitin synthesis and methods for interfering with the process. Work will continue on the screening of candidate compounds, and small-scale tests will be carried out against the jack pine budworm and Swaine jack pine sawfly. Biochemical studies on the physiological action of IGR will continue.

FP-7

GENETIC MECHANISMS

PROJECT LEADER

in abeyance

OBJECTIVES

To analyze the genetic components of insect reproduction and to investigate methods for manipulating pest abundance by genetic means.

ACHIEVEMENTS

Since the project was initiated in 1972, chromosome numbers and sex-determining mechanisms have been determined for more than 100 species of Lepidoptera. These mechanisms have provided a clearer understanding of the genetic complement of this group of insects. Genetic studies, carried out in collaboration with staff at GLFRC, have concentrated on the *Choristoneura* group and have included analyses of chromosome relationships in seven species and their hybrids. The use of sterility to reduce population levels has been intensively investigated, with basic studies being carried out on mechanisms for inducing sterility, effects on treated

insects, and reduction in population fertility resulting from introduction of sterile adults. The dispersal of released adult males was determined using pheromone trapping techniques. The effects of various sterilizing treatments on the ability of males to respond to pheromone attractants was also studied. Results to date indicate that the potential of this method lies with low-level isolated populations rather than large-scale epidemics.

This project was placed in abeyance in 1980 after the move of the project leader into a management position.

PROJECTIONS Reactivation of the genetics project at the Institute will depend on availability of Person Year resources. The direction of the research is dependent on the type of genetics input required by other Institute projects in biological control.



Chemical Control Research

A wide variety of forest insect pests inflict severe damage on Canadian forests each year. The best estimates currently available suggest that the average loss in wood volume caused by the activities of our major forest insect pests approaches or exceeds some 63 million m³ per annum. Losses of this dimension cannot be tolerated if Canada is to meet wood production goals accepted by the Canadian Council of Resource and Environment Ministers for the year 2000, or if we are to maintain Canada's share of the foreign market in wood and wood products, which is so vital to our national economy. Such losses can be prevented or at least reduced substantially by the judicious use of chemical insecticides. Most chemical insecticides, however, are developed by the pesticide industry first for the agricultural use market, which is very large and stable as compared to the forestry use market. Before such materials can be registered and used for forestry purposes, it is essential that their efficacy against forest insect pests be determined and that dosage rates that will balance efficacy and acceptable environmental impact be established.

To help ensure that forest managers have a range of effective chemical insecticide alternatives available for their use, the Institute maintains a continuing program that screens new insecticides and modifies formulations of existing ones, to determine toxicity against a range of forest insect pests. Those insecticides that appear to have potential for forestry use are tested in a series of field efficacy trials to establish actual use potential, required dosage rates, and use patterns. The data generated by this program become essential components of the data package that is eventually submitted in support of registration of these pesticides for forestry use under the Pest Control Products Act.

FP-12

TOXICOLOGY & SCREENING OF CHEMICAL
INSECTICIDES

PROJECT LEADER

B.V. Helson

SUPPORT STAFF

J.W. McFarlane

D. Comba

OBJECTIVES

To determine the basic toxicological effects of insecticides and their formulations against forest insect pests and selected nontarget organisms and, for those that show potential for forestry use, to provide projected dosage levels and optimal droplet sizes for further field testing.

ACHIEVEMENTS

Since the inception of this project, approximately 100 insecticides have been tested against some 25 major pests. Chemical insecticides such as fenitrothion, aminocarb, and acephate, which are now registered for large-scale forest insect control, were originally identified through this program. Within the past few years the study has provided information on pyrethroid insecticides, solvents, and carriers used in spray formulations. Permethrin, chlorpyrifos-methyl, Bolstar, solvent 585, and a Matacil flowable formulation have been recommended for field evaluation.

The lateral transfer of the Project Leader to the Maritimes Forest Research Centre (MFRC) took place in May 1982; the new Project Leader assumed responsibility for the program at the end of June 1982. Preliminary contact toxicity tests were conducted to determine the susceptibility of 3rd and 4th instar, field-collected spruce budmoth larvae to aminocarb and fenitrothion. Several insecticides and formulations were tested against spruce budworm larvae to determine their direct contact toxicity, their residual toxicity under natural weathering conditions, and their toxicity as foliar deposits. Studies on the contact and residual toxicity of Matacil 180F were completed in 1982. The toxicities of aqueous mixes of fenitrothion and aminocarb containing the emulsifiers Triton-X-100 or Triton-X-114 against spruce budworm larvae were assessed in the laboratory as part of the CFS/FPML Action Plan to identify emulsifiers to replace Atlox 3409F. Cooperative

studies were continued with the National Research Council to determine the effects of droplet size on the toxicity of insecticides to spruce budworm larvae.

PROJECTIONS

During 1983-84, toxicological investigations will be continued with Sumithion Flowable, a new Zectran formulation under development by Union Carbide, and a variety of numbered experimental compounds that may have potential for forestry use. In addition, and in cooperation with other research groups at the Institute, toxicological screening for effective compounds against spruce budmoths, *Zeiraphera* spp., will be continued. Cooperative approaches to the determination of the dimensions of biologically effective buffer zones to protect aquatic habitats from pesticide drift by ground-spray application of insecticides will also continue.

FP-13

FIELD EFFICACY, CHEMICAL & BIOLOGICAL CONTROL

PROJECT LEADER

B.L. Cadogan

SUPPORT STAFF

B.F. Zylstra P. Ebling
C. Nystrom P. deGroot
L.B. Pollock

OBJECTIVES

To assess the efficacy of new insecticides, formulations, and pest management strategies for forestry use.

ACHIEVEMENTS

Since its inception in the mid-1950s, this project has been concerned primarily with field efficacy testing of insecticides with potential for forestry use. Data arising from this project have been utilized to assess the efficacy of virtually all insecticides currently registered for forestry use in Canada today and to improve methods of applying these materials in a manner that optimizes effectiveness while maintaining adverse environmental impact at acceptable levels. During

recent years, the project has investigated the efficacy of chlorpyrifos-methyl, permethrin, carbaryl, and aminocarb flowable formulations and has provided virtually all of the efficacy data that contributed to the registration of permethrin and aminocarb flowable for forestry use in Canada.

During 1982, investigators within this project were heavily involved in the New Brunswick based spray trials that formed a significant element of the FPML/CFS Action Plan to find alternative emulsifiers (to Atlox 3409F) for fenitrothion and aminocarb water emulsion tank mixes. In addition, spray trials conducted by this project demonstrated that 6N insecticide diluent was not in itself toxic to budworm larvae when sprayed from the air at dosages equivalent to its normal use as an insecticide spray diluent. Also during this period, calibration trials of the Institute's newly acquired Cessna Ag Truck spray aircraft were undertaken.

PROJECTIONS During 1983-84, field studies will concentrate on assessment of deposit characteristics and efficacy of fenitrothion and aminocarb flowable water-based sprays with the emulsifier Triton-X-114 replacing Atlox 3409F in the tank mixes. Cooperative work will be done with the Institute's virology project on the application of spruce budworm nuclear polyhedrosis virus as an early-instar spray. Calibration trials with the Institute's new aircraft will be completed.

Application Technology

The ultimate goal in the operational application of any pesticide by whatever application method is to assure that only the minimum required amount of the pesticide is emitted, and that as much of the emitted material as possible reaches the intended target in a form that optimizes its effectiveness against the target pest. If this goal is achieved, drift beyond the target areas is minimized as is the impact of the pesticide on nontarget components of the environment.

A great number of factors affect achievement of this ultimate goal. For example, the physico-chemical characteristics of liquid sprays affect the production, size, and evaporation of the spray droplets. Nozzle type, pressure, flow rate of the emission system, and speed of the vehicle carrying the emission system also influence the droplet pattern produced. Meteorological conditions during application affect the movement of the spray cloud, evaporation of the droplets, and penetration into and impaction on the forest canopy.

A thorough understanding of all of these factors and their interactions is essential if pesticides are to be applied in the most economical, efficacious, and environmentally acceptable manner. Therefore, research into all of these areas is an important aspect of the Institute's overall R & D program.

FP-8**PESTICIDE DISPERSAL SYSTEMS &
DEPOSIT ANALYSIS****PROJECT LEADER**

Vacant

SUPPORT STAFF

A. Obarymskyj

OBJECTIVES *To test and assess new spray emission systems on aircraft and ground spray equipment for improved pesticide applications.*

ACHIEVEMENTS Research carried out during the 1960s on the basic principles of ultra-low volume application technology resulted in the introduction of incremental application technology of wide swath spraying using multi-engine aircraft, full span above-the-wing boom and open nozzle spray system, and electronic guidance systems for accurate swath alignment.

A simple, compact, efficient, folding, flat-plate sampling unit was developed to ensure rapid retrieval of spray deposit data in order to provide reliable cumulative deposit results from both research and operational sprays. A compact emergence box was developed for the collection of 2nd- and early 3rd-instar budworm larvae from whole branch samples.

With the retirement of the project leader in December 1981 and the pressures of high-priority work programs (New Brunswick Action Plan), it was decided to delay staffing the project leader position, and to assign the technician to another project.

PROJECTIONS Staffing action for a professional to head up this project through the Department's Francophone recruitment program has to date been unsuccessful but efforts will continue through 1983-84. The project, when staffed, will concentrate on the modification and development of spray emission hardware that will produce pesticide spray clouds for forestry use with physical characteristics that will optimize efficient and effective deposit on target areas and reduce off-target drift.

FP-9

SPRAY KINETICS & PHYSICS

PROJECT LEADER

SUPPORT STAFF

A. Sundaram

J.W. Leung

OBJECTIVES

To determine the physical and chemical characteristics necessary for the development of efficacious. environmentally acceptable spray mixes.

ACHIEVEMENTS

This project was initiated in 1980. During 1980-82, the project investigated the physical properties of various pesticide formulations, tank mixes, and component materials to determine their viscosity, density, surface tension, evaporation rate, and the influence of these factors on emission characteristics through a range of emission systems. A variable speed wind tunnel - spray chamber was constructed to study droplet production characteristics on a variety of targets in the laboratory. Actual deposition and distribution of droplets of various sizes on coniferous foliage were assessed in the field, using a new formulation that provided in-flight microencapsulation of droplets. All of this work has provided a new capability to the Institute that, when combined with other elements of the application programs, will undoubtedly lead to improved technology for applying pesticides in forest situations.

During 1982-83, this project was involved in the FPPI/CFS Action Plan to find replacement emulsifiers (to Atlox 3409F) for fenitrothion and aminocarb flowable insecticides. Knowledge gained during the earlier years of the project led rapidly to the selection of the Triton series of emulsifiers as the most appropriate candidates. Tank mixes of emulsifier and diluents that would provide the sprays with suitable physical characteristics were also identified. The project also continued assessment of physical and kinetic properties of a wide range of tank mix components; participated in a CANUSA field study on the efficacy of *B.t.* against spruce budworm as related to droplet size and deposit; and completed modification and calibration of the Institute's wind tunnel - spray chamber.

PROJECTIONS During 1983-84 the project will be involved in investigations of formulation and tank mix characteristics of new Sumithion Flowable and Zectran Formulations, the feasibility of using a laser Doppler Velocimeter for accurate assessment of droplet size and density in the spray chamber, and in cooperative research with other elements of the Application Technology Program and other projects at the Institute.

FP-10

METEOROLOGICAL PARAMETERS

PROJECT LEADER

N. Payne
(March 22/83)

SUPPORT STAFF

W.J.G. Beveridge

OBJECTIVES *To determine the effects of weather parameters on spray cloud drift and deposit and to develop guidelines for spray operators for most effective spray application.*

ACHIEVEMENTS This project functioned without a project leader from 1978 to the end of this fiscal year. During this time, the technician in charge carried out a research project to generate information on tree canopy turbulence and participated in joint research projects with other groups.

Extensive weather measurements were carried out at a research site on St. Joseph Island, near Sault Ste. Marie, to study the temperature, relative humidity, and turbulence from ground level through the tree canopy to clear air above the canopy. These studies showed that the classical temperature and turbulence profiles can be measured. Studies were also carried out to measure the changes in these profiles throughout the day and night at regular intervals of time. A new tower-instrument sensor system was developed to carry out this work. A computer program was developed and written in cooperation with the Biometrics Unit of the Great Lakes Forest Research Centre. Spray deposit assessment studies, under known weather conditions, were initiated in a joint project with the Field

Efficacy project. The Grim-Barry-Cramer spray cloud dispersal model was obtained from the USDA Forest Service. A solar powered, recording weather system was tested and calibrated for the Environmental Impact project: it was then installed at the Icewater Creek site for long term weather studies.

PROJECTIONS Staffing Action was commenced in late 1982-1983, and it is expected that the candidate will be on staff by spring 1983. Once on staff, the Project leader will conduct an in-depth project analysis that will guide the course of this project, and its interaction with other elements of the Institute's programs for the immediate future.

FP-11

SPECIAL APPLICATIONS

PROJECT LEADER

J. Turgeon

SUPPORT STAFF

N. Charlebois

OBJECTIVES *To identify and make recommendations for the control of pest insects of plantations. woodlots and seed production areas.*

ACHIEVEMENTS This project was initiated in 1970 to study plantation insect pests. Research was carried out on weevils, shoot borers, and midges that affect spruce and pine plantations. Control recommendations were made for these pests. Research using mistblowers, hydraulic sprayers, helicopters and fixed-wing aircraft conducted by this project led to provision of guidelines for the most effective use of these spray vehicles. In 1981 the project was reorganized, with emphasis to be placed initially on the identification of insects affecting seed and cone production on conifers and on the development of effective techniques for their control.

The current Project Leader joined the Institute staff in the spring of 1982. It was determined that spruce budmoths, *Zeiraphera* spp., were inflicting severe damage on valuable white spruce plantations in New

Brunswick and it was decided that this problem warranted immediate emergency treatment. In 1982-83, the project began an investigation in New Brunswick of the biology and behavior of the spruce budmoth to define the problem and to determine critical points in the life cycle where control might be applied. Extensive work during the summer of 1982 showed that *Z. canadensis* was the most common budmoth species present. The life-cycle, behaviour, and the nature of the damage inflicted by the insect were studied. These studies indicated that the insect would not be easily controlled by the usual approaches. Therefore, it was decided late in 1982-83 that problems of this nature would best be investigated through a team approach (biologist - behaviourist and a control specialist) and the decision was made to add a control specialist to the project. This was accomplished through staff realignment within the Institute in the winter of 1982-83.

PROJECTIONS

FP-11 will be renamed Insect Ecology and Biology, and the new project will be called High Value Stand Protection. Emphasis in the former will be on completion of biological studies in preparation for initiation of studies on insects affecting seed and cone production in 1984-85. The latter project will initiate field testing of candidate control products and application techniques in 1983-84, complete these in 1984-85, and move into similar studies on seed and cone insects in 1985-86.

Herbicides Research

As Canada becomes increasingly committed to a program of intensive forest management to meet future wood and fibre requirements, productive forests must be re-established on cutover sites. An ever increasing backlog of inadequately regenerated cutover areas must also be returned to production. On such sites, competition from brush, undesirable tree species, grasses, and weeds often impedes the establishment, survival and growth of desired crop species. Control of such competing vegetation may easily double the productivity of such sites.

Traditional hand and mechanical methods of removing competing vegetation are labor-intensive and extremely expensive. In addition, the effectiveness of these methods is often limited because the undisturbed root systems continue to utilize soil moisture and nutrients, and produce a new crop of competing vegetation before the desired species can react sufficiently to the release treatment.

Intelligent use of chemical herbicides provides an alternative to traditional vegetation control methods, one that is more effective, less costly, and simpler to implement.

Because of the potential for use of herbicides in intensive forest management, and the lack of suitable materials registered for forestry use in Canada, the Institute added herbicides research to its program in 1981. This project will develop new herbicides for forestry use, and strategies for using existing and new materials in the most effective yet environmentally conscious manner.

FP-19

TOXICOLOGY & SCREENING OF HERBICIDES

PROJECT LEADER

P. Reynolds

SUPPORT STAFF

R. Prasad

D. Travnick

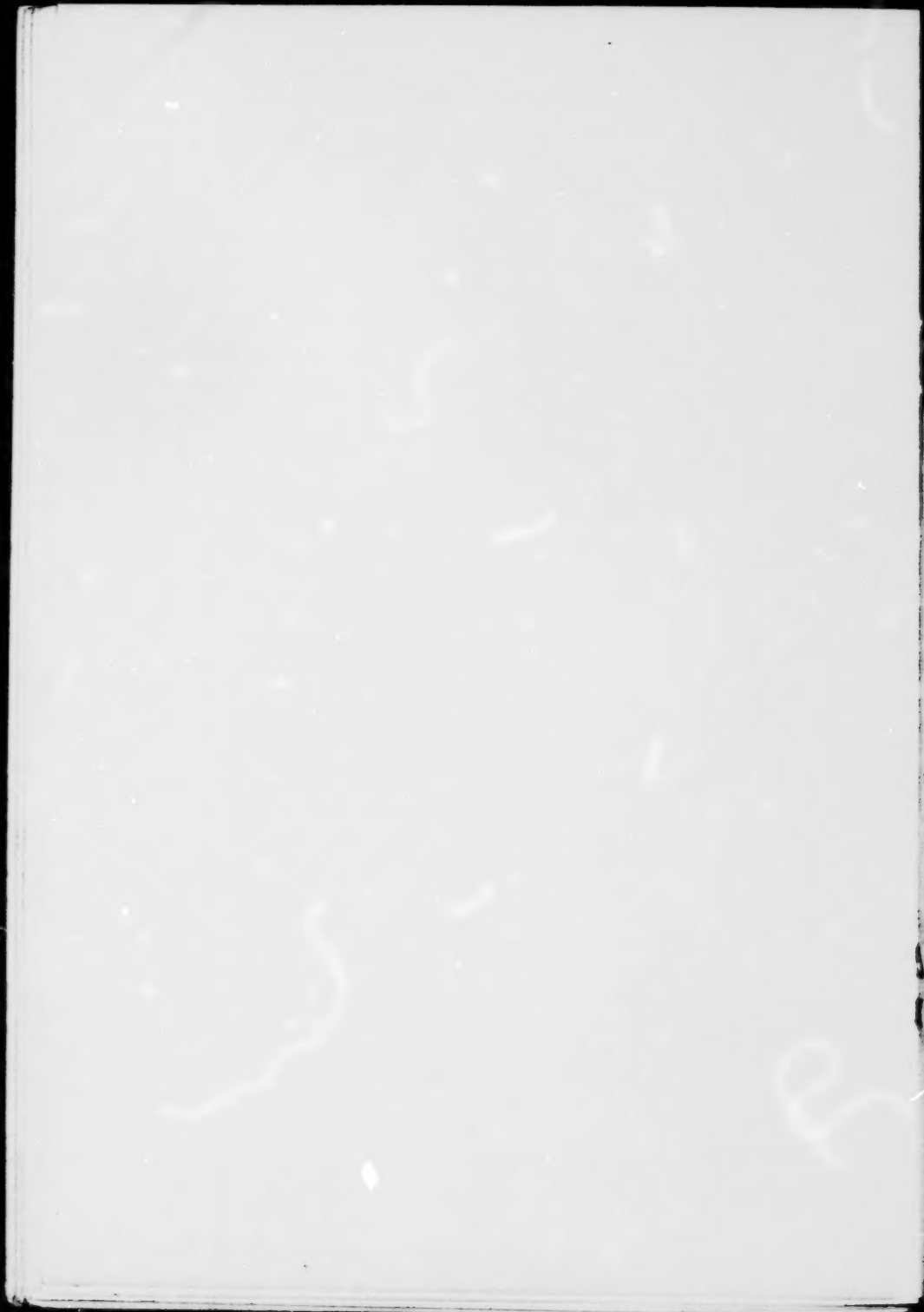
OBJECTIVES *To evaluate and provide recommendations for the use of new and improved herbicides for vegetation management in Canada.*

ACHIEVEMENTS The FPMI herbicides project was initiated in 1981 in response to concerns that had been expressed by forest managers about the scarcity of vegetation management tools. A scientist and technician were assigned to the project to identify new compounds with potential for forestry use and to compile a comprehensive data base on existing materials. Visits to various sources of expertise on herbicide use and development emphasized the need to develop new herbicides for use in site preparation and conifer release, to determine their precise modes of action. Improved formulations, tank mixes, and application techniques could then be developed that would allow essential herbicides to be applied more effectively and without undesirable side effects.

During 1982-83 a comprehensive protocol was established for the evaluation of new herbicides under laboratory, greenhouse, and field conditions. Six herbicides showed promise, and Garlon, Velpar, Glyphosate, Herbec-29 and Spike-80 were identified for further testing. Basic studies on the penetration, translocation and metabolism of 2-4D and Glyphosate were carried out. Fact sheets were prepared for a number of herbicides with potential for forestry use. The position of researcher responsible for field-oriented herbicides research was staffed.

PROJECTIONS The status of herbicide research and development in Canada will be reviewed in 1983-84. Herbicide use and testing sites throughout the country will be visited and the Institute's herbicide research staff will develop a comprehensive project analysis. Work on the toxicology and screening of herbicides will continue.

**ENVIRONMENTAL
AND
AMENITY
FORESTRY**



Environmental Impact & Chemical Accountability

Before a pesticide can be used in Canada, it must be registered under the Pest Control Products Act, which is administered by Agriculture Canada. Under the terms of this Act, a pesticide must be proved effective and its use must not have a significant, adverse impact on environmental quality or on human health. To have such materials registered for forestry use in Canada and to develop the most appropriate use patterns for them, it is essential that we have an adequate understanding of their impact on nontarget, naturally occurring species in the forest environment, and of their persistence, mobility, and ultimate fate in that environment. While such knowledge is essential for registration purposes, it is just as essential in adequately addressing public concerns relating to the use of these forest management tools.

A significant portion of the Institute's technical expertise and resources are directed toward determination of the effect of pesticides (chemical and biological) on nontarget avian, terrestrial, and aquatic organisms in the forest environment and to elucidation of the occurrence and fate of these materials, and their breakdown products in foliage, soil, litter, water, and bottom sediment after application.

FP-15

ENVIRONMENTAL IMPACT OF PEST
MANAGEMENT STRATEGIES

PROJECT LEADER

P.D. Kingsbury

SUPPORT STAFF

S.B. Holmes

B.B. McLeod

K. Mortensen

D.P. Kreutzweiser

R.L. Millikin

OBJECTIVES *To provide the necessary ecological data to ensure that pest management strategies used in Canadian forests are environmentally acceptable.*

ACHIEVEMENTS This project has worked with other projects and Provincial agencies in tests to assess the environmental impact of new insecticides for the control of forest pests. Prior to 1982, field studies were carried out to assess the impact of products such as fenitrothion, aminocarb, acephate, phosphamidon, carbaryl, permethrin, chlorpyrifos-methyl, *Bacillus thuringiensis*, nuclear polyhedrosis virus, juvenile hormone analogues, and insect growth regulators. Methodologies for assessing the impact of pest control strategies were evaluated.

During 1982-83, the collection of additional baseline data in the Igewater Creek research area was continued. Studies were carried out on forest songbirds, fish, ground insects, aquatic invertebrate populations and their emergence patterns, pollen and nectar source phenology and their use by honeybees and wild pollinators. Evaluation of the environmental impact of three field formulations of Matacil 180F applied under semioperational conditions in New Brunswick and Quebec was completed. Sufficient data was generated demonstrating a lack of serious environmental effects to allow the granting of full registration status of this material for spruce budworm control in Canada. Studies were done on the environmental impact of three CFS Action Plan field formulations based on Triton-X-100. Acute toxicity tests were carried out on rainbow trout with all Action Plan formulations, including those based on Triton-X-114. Positive steps were taken to initiate closer ties with the Canadian Wildlife Service in pesticide-wildlife studies.

PROJECTIONS During 1983-84, baseline data collection in the Ice-water Creek research area will be completed to the extent that aerial application of pest control products can be considered for 1984. The toxicology of various insecticides to some important pollinating insects will be determined in cooperation with the Institute's toxicology and chemical insecticide screening project. Songbird populations in spruce budworm-killed and damaged stands will be assessed.

FP-16

CHEMICAL ACCOUNTABILITY OF PEST CONTROL PRODUCTS

PROJECT LEADER

K.M.S. Sundaram

SUPPORT STAFF

J. Feng

C. Feng

R. Nott

OBJECTIVES *To develop techniques for, and to provide knowledge on, the measurement of pesticide residues and their metabolites in the forest ecosystem.*

ACHIEVEMENTS The research of this project has provided basic data which has been used to support applications for registration of fenitrothion, acephate, and aminocarb. Methodologies have been developed for the measurement of pesticide residues.

Slight changes were made in the goals for 1982-83 to accommodate the CFS Action Plan studies. Investigations were conducted into the environmental behavior and fate of aminocarb and fenitrothion in New Brunswick forests: it was determined that fenitrothion is present in detectable levels in various forestry substrates. Field studies of the newly introduced Matacil 180F formulations confirmed that the new formulations have negligible toxicity, and are therefore ecologically acceptable. Studies to evaluate stability, persistence, and fate of new formulations of aminocarb and fenitrothion containing Triton-X-100 showed that the new emulsifier produced equally satisfactory tank mixes with the two insecticides, and the new formulations are

comparable to the conventional formulations containing Atlox 3409F. Air current studies under simulated aerial spray conditions showed that additives play a significant role in determining foliar deposition, persistence, and droplet distribution on collection units. An impinger technique to collect airborne pesticides has been developed and used to monitor residue levels of fenitrothion and aminocarb in air samples from research spray blocks in New Brunswick.

In the laboratory, a simple, inexpensive microcolumn cleanup technique has been developed for the quantification of aminocarb and fenitrothion residues in various forestry substrates.

PROJECTIONS During 1983-84, samples will be taken from sites in New Brunswick where unexpected fenitrothion residues were found in 1982-83. These samples will be taken in the spring of 1983, before operational spray programs begin and will be analyzed to determine the persistence of these residues. Methodologies will be developed for the analysis of residues of Zectran and Sevin in various forest substrates. This project will participate with others at the Institute in field trials to determine biologically effective buffer zones for ground spray application of permethrin in forest plantations. Participation in the Federal Interdepartmental Committee on Pesticides (FICP) Check Sample program will continue.

**COMPLEMENTARY
RESEARCH
&
SERVICES**



Complementary Research & Services

There are four areas of research in the Institute's program that have, in addition to their significant individual contributions, strong ties with various projects. These areas are Cell Biology, Tissue Culture, Serology, and Computer Applications. Prior to 1980, their activities were fragmented throughout the Institute program. In 1980-81, Cell Biology, Tissue Culture and Serology were consolidated as studies within this project. Systems analysis capability was added to acknowledge the need for an integrated complex information from a variety of areas. Reorganization in this manner reflected the broader interaction of these disciplines within the Institute program.

The Institute also requires a strong service base in Insect Production, Pathogen Production, Pathogen Identification and Greenhouse Services. To be most effective these have been organized into discrete service sections and included in one Complementary Services Project.

FP-17-1

CELL BIOLOGY

PROJECT LEADER

J.E. Percy

SUPPORT STAFF

J.A. MacDonald

D.E. Pawlik

OBJECTIVES To determine the ultrastructural characteristics of insect cells and tissues involved in production of biologically active agents as well as the modification of cells and cuticle resulting from the penetration and internal distribution of insect pest control agents in order to enhance the effectiveness of these agents.

ACHIEVEMENTS The production and transport of pheromones have been determined at the cellular and subcellular levels in several insect species. Such studies also identified more general mechanisms of transport of biologically active materials through cells and insect cuticle. Co-operative research with other projects has resulted in an examination of the mode of action of *Bacillus thuringiensis* (B.t.) endotoxin on gut cells, determination of the development and structure of a microsporidian infecting the larch sawfly, confirmation of the replication of the Douglas-fir tussock moth nuclear polyhedrosis virus (NPV) in an established cell line, and development of techniques for the study of virus replication in other cell lines. Other viruses from field-collected insects have been identified. Studies were completed on the ultrastructure of the pheromone gland of the forest tent caterpillar, on the mode of action of B.t. on gut cells, and on the presence and replication of tussock moth virus in cell lines. Additional identification has been made of pathogens in field-collected insects.

During 1982-83, controlled experiments were initiated to assess nuclear and nucleolar changes as early indicators of virus infections in spruce budworm larvae. A study on the ultrastructural indicators of precocene toxicity in the Oleander hawkmoth was initiated and completed. An analysis of ultrastructure of wax gland cells in larvae of *Eriocampa ovata* and the chemical analysis of the secretion has been completed. Confirmation of the replication of Douglas-fir nuclear polyhedrosis virus (NPV) in *Orgyia leucostigma* cell lines has been completed.

PROJECTIONS The Project Leader will be on career development leave at the University of Texas, Austin, to gain expertise in the development of insect larval tissues and organs, so that interference with these processes by applied control agents can be better understood and exploited. Work will continue on determining cellular and sub-cellular changes associated with the production of pheromones, cuticular waxes and hormones, and on the cellular effects of pathogens, infections, and chemical pesticides.

FP-17-2

TISSUE CULTURE

PROJECT LEADER

S.S. Sohi

SUPPORT STAFF

G.F. Caputo

B.J. Cook

OBJECTIVES *To develop and apply insect tissue methodology for the in vitro investigation of insect pathogens with a view to enhancing their effectiveness in the management of forest insect pests.*

ACHIEVEMENTS Since 1965, over 30 continuous cell lines have been established from tissues of spruce budworm, forest tent caterpillar, whitemarked tussock moth, redheaded pine sawfly, and tobacco hornworm. Nuclear polyhedrosis viruses (NPV) of the original hosts have been propagated *in vitro* with these cell lines. Microsporidia have also been propagated, but to a more limited extent. Multiplication and morphogenesis of viruses and microsporidia in tissue culture have proved similar to those of pathogens grown *in vivo* and they remained infectious to the original hosts. A cell-based bioassay was developed for the *Bacillus thuringiensis* (B.t.) toxin using spruce budworm cell lines. Methods have been developed for large-scale propagation of cells, as well as for long term deep-freeze storage and recovery of insect cell lines. Several cell lines have been characterized by chromosome number and serological relationships. The NPV of both the whitemarked and Douglas-fir tussock moths grew very well in cell lines

derived from whitemarked tussock moth. Conditions for optimal multiplication were determined.

During 1982-83, characterization of *Orgyia leucostigma* cell lines were completed. Ten primary cultures were isolated from pupal ovaries of *Choristoneura fumiferana*. Preliminary tests with *C. fumiferana* NPV have given very encouraging results, with replication in up to 80% of the cells. Over 60 primary cultures were isolated from ovaries, hemocytes, and neonate larval tissues of *Choristoneura occidentalis*.

PROJECTIONS Work will continue on the development of *in vitro* bioassays for viral virulence and on the determination of conditions necessary for optimum replication. Development will continue on cell lines of *Choristoneura fumiferana* and *Choristoneura occidentalis* that will support high levels of NPV application. The growth characteristics of a sawfly cell line will be improved.

FP-17-3

SEROLOGY

PROJECT LEADER

Vacant

OBJECTIVES To develop and apply immunochemical and serological techniques to the identification and characterization of microbes and insect cell cultures.

ACHIEVEMENTS Serological studies at the Institute have been closely allied to other biological control projects for the past 25 years. A large number of *Bacillus thuringiensis* (B.t.) strains and isolates have been identified and characterized, contributing to a fuller understanding of taxonomic relationships. This work identified a number of isolates with greater specific toxicity than that found in commercial preparations. The adaptation of a new assay technique led to quantitation of the toxic protein crystal control of various B.t. isolates. Serological techniques have also been

applied to characterization of viruses being studied at the Institute, and to identification of insect cell lines maintained here.

The project leader retired from the Institute in June, 1982. Accumulated results to that date have been provided to cooperating scientists for eventual inclusion in journal publications or other information activities.

PROJECTIONS With the retirement of the Project Leader, this project will be reoriented towards the serological and immunochemical characterization of insect pathogens as well as to the application of immunochemical techniques to the modification and improved virulence of insect pathogens.

FP-17-4

COMPUTER APPLICATIONS

PROJECT LEADER

Vacant

OBJECTIVES *To plan, organize and carry out studies on the biology and population dynamics of forest insect pests and to provide consultation, advice, and assistance to other researchers planning on developing models of biological or physical systems related to pest management.*

ACHIEVEMENTS This project was initiated in 1980. Between 1980 and mid-1982 a comprehensive review of the literature on modeling in forest ecosystems, and in particular the spruce budworm, was completed. Two cooperative projects with FPPI investigators were initiated. Problem definition, system-environment dichotomy, and variables that affect the system were identified.

The project leader responsible for this project transferred to Agriculture Canada in May of 1982. Since then, the project has been in abeyance pending recruitment of a new systems scientist.

PROJECTIONS Recruitment of a Project Leader in 1983-84 will provide the Systems Analysis capability required by Institute for successful development and integration of a wide range of control methods as coherent options for the forest manager. As well, modeling efforts will begin on a variety of entomological and pathological problems, such as the dynamics of host-pathogen interaction and the response of insect populations to applied control agents.

FP-18-1

INSECT PRODUCTION

SUPPORT STAFF

D.G. Grisdale	W.A. Bodley
A.R. McMorran	P.B. Naphan
L. Harwood	K. Barratt
C.B. Budau	

OBJECTIVES *To develop and carry out insect rearing methods that will provide the numbers and varieties of insects required by Institute research projects.*

ACHIEVEMENTS Since 1963, the insect rearing capability of this section has been developed into the largest of its kind in Canada, supplying insects not only to FPMI but also to various CFS establishments, universities and other research centres in Canada and the U.S. During 1982-83 seventeen species were reared including *Choristoneura fumiferana*, whitemarked tussock moth and western spruce budworm. Emphasis on production shifted from *C. fumiferana* to *C. occidentalis*, as the latter is better suited to virus production. Over 6 million insects were produced, of which two-thirds were used at the Institute for pathogen production or research. The remainder were shipped to cooperating agencies.

PROJECTIONS Production will continue at a very high level, with the types and numbers reared depending on demand.

FP-18-2**PATHOGEN PRODUCTION****SUPPORT STAFF**

J.R. McPhee

H.M. Wigney

OBJECTIVES *To produce sufficient insect pathogens to meet Institute research needs.*

ACHIEVEMENTS To date, pathogen production has been devoted exclusively to insect viruses. Since 1970, the section has provided FP-4 (Viral Pathogens), with sufficient spruce budworm virus to treat over 2000 ha. In addition, adequate virus has been produced to treat 80 ha of western spruce budworm infestation, 1200 ha of Douglas-fir tussock moth, 50 ha of European pine sawfly, 1600 ha of redheaded pine sawfly and 40 ha of forest tent caterpillar, plus small populations of Bruce's spanworm and winter moth.

During 1982-83, the virus production unit provided Douglas-fir tussock moth nuclear polyhedrosis virus (NPV) for cooperative trials with Pacific Forest Research Centre (PFRC) and the British Columbia Ministry of Forests (BCMF). Western spruce budworm NPV and granulosis virus (GV) were supplied to the viral pathogens project for use in a cooperative trial with PFRC in British Columbia. Redheaded pine sawfly NPV was produced for use by FPML and Ontario Ministry of Natural Resources staff. Western spruce budworm was found to be a better producer of virus, and emphasis in production has shifted to this insect.

PROJECTIONS Virus production will continue, with the particular viruses being produced to be determined by Institute research needs. Capability for microbiological quality control in virus production will be established.

FP-18-3**DISEASE DIAGNOSIS****SUPPORT STAFF**

Vacant

OBJECTIVES *To provide disease diagnosis services to the Institute and to identify new pathogens and their effects on host species.*

ACHIEVEMENTS The disease diagnosis section has for many years identified pathogens occurring in field-collected insects from Canada and other countries. These continuing surveys of diseased material have yielded several new isolates of various pathogens, and have provided information on the distribution and frequency of pathogens in insect populations. The incidence of pathogens (viruses, fungi, microsporidia) in developing and declining spruce budworm populations has been monitored in several regions of Ontario over a seven-year period. In addition, pest insect species that do not appear to have a significant, naturally occurring disease complex are screened for susceptibility to the pathogens on hand, to determine whether any offer control potential.

In 1982-83, in anticipation of the Study Leader's retirement, studies were consolidated and published as Internal or Information Reports.

PROJECTIONS This study will be terminated and the Person Year (P/Y) resource re-allocated within the Institute program. The disease survey function will end, with any pathogen identification necessary to be carried out by staff of other projects.

FP-18-4**GREENHOUSE & ANIMAL SERVICES****SUPPORT STAFF**

D. Buckley

N. Lautenslager

OBJECTIVES *To operate greenhouse and animal rearing facilities that will provide, as required, material for Institute research use.*

ACHIEVEMENTS Greenhouse facilities have been established that can provide a broad range of plant material for use in bioassays, insect production, single tree experiments and application technology development. Flushed potted trees are available nearly year round and enable screening activities and host-insect research to be carried out on a continuous basis. The animal facility maintains small mammals required for the Serology and Viral Biochemistry studies.

During 1982-83, capability for production of flushed potted trees was increased. As well, capability for production of seedlings and cuttings of various pest vegetation species was increased to support new initiatives in herbicide screening.

PROJECTIONS Production will be maintained, with species produced to be determined by research requirements. Production of potted trees for bioassay tests, and vegetation for herbicide screening, will continue to increase.



**INFORMATION
&
TECHNICAL
SERVICES**



Information & Technical Services

No research is complete until the results have been transferred effectively to potential users. The research and development (R & D) program of the Institute is broad and complex and interfaces closely with other federal departments, other governments, provincial forest management agencies, private industry, environmentalist groups and the Canadian public. R & D emanating from the Institute's program must, therefore, be transferred to user groups in various forms which promote and facilitate its use. While the scientists concerned with the Institute's R & D program develop technical data and scientific publications related thereto, it is essential that:

- An editorial capability in both official languages be provided ensuring adherence to accepted publication policies.
- The packaging and format of reports and publications be developed and modified to meet changing demands.
- Reports and publications emanating from the Institute on a regular basis (e.g., Program Reviews, Newsletters, etc.) be prepared and issued on schedule.
- Mailing lists and circulation lists be developed and maintained in an up-to-date fashion.
- Requests for information be satisfied in a timely fashion.

The Information and Technical Services Unit at the Institute provides these and other services contributing in a significant manner to our overall program.

FP-95**SCIENTIFIC EDITING & INFORMATION SERVICES****PROJECT LEADER**

Vacant

OBJECTIVES *To publish and disseminate scientific and technical information emanating from the Institute's program in the most appropriate form to facilitate the transfer of forest pest management science and technology to user groups.*

ACHIEVEMENTS After the staffing of the position of project leader in 1980, the project provided liaison, technology transfer, and information services. Since then, the project has significantly upgraded the Institute's publication cataloguing, inventory and storage capabilities; developed quick-reference information files on pesticides and pest management practices; initiated a photograph and color transparency library; consolidated mailing lists; instituted an effective manuscript review and production procedure; and handled other items such as news releases, tours of the facility and organizing of meetings and workshops on forest pest management matters.

During 1982-83, the backlog of Information Reports requiring publication in the French language was reduced significantly. Twenty-one journal papers, 10 information and 19 miscellaneous reports were published. During the year, 4,308 journal reprints and 3,230 information reports were distributed. Late in the 1982-83 year, the Project Leader accepted a transfer to the Pacific Forest Research Centre. After a management review it was decided to drop the liaison function that was originally the responsibility of this project and to address these needs through professional R & D staff and Institute management staff. Because the Institute's program is virtually exclusively research and development, it was decided that the scientific editing and publications function should be the prime function of this project. Staffing action was initiated for the positions of a bilingual Scientific Editor, a French Editor, and a term casual drafting and design technician, and arrangements were made with GLFRC to obtain adequate working and office space for the staff involved.

PROJECTIONS

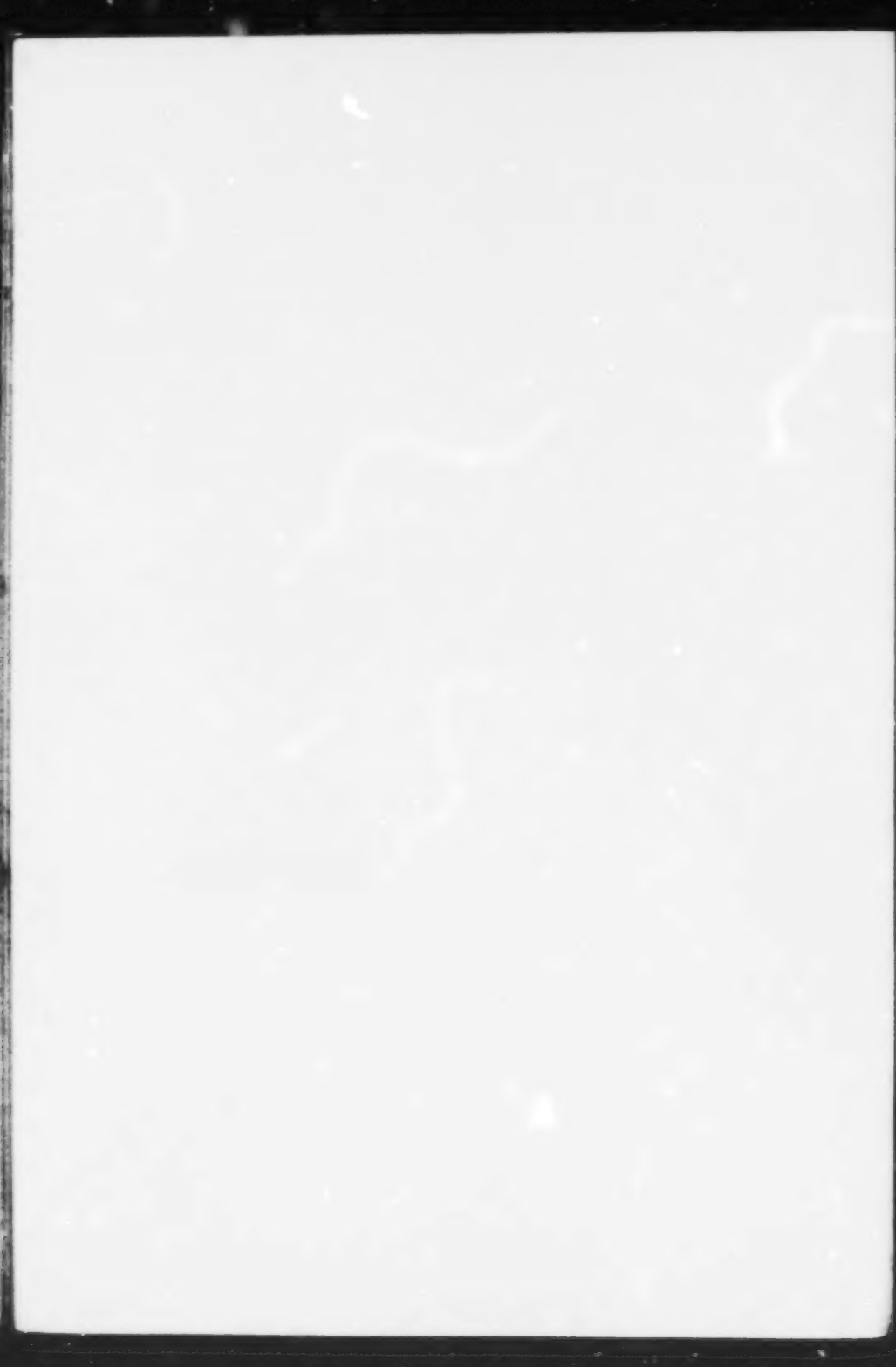
During 1983-84 staffing of Scientific Editor, French Editor and a Drafting Design Technician positions will be initiated. Increased working space negotiated with GLFRC will be occupied, Institute displays will be converted to the bilingual format, manuscript editing and review procedures for the Institute will be updated, and a continuing high level of Scientific Editing and information will be maintained.



ADMINISTRATION

&

**COMMON
SUPPORT
SERVICES**



Administration & Common Support Services

Administrative Support Services (material management, records management, office services, fleet management, operation and maintenance of physical plant) and financial services are provided to both the Forest Pest Management Institute and the Great Lakes Forest Research Centre through one administrative unit carried on the Great Lakes Forest Research Centre allocation but responsible to the Directors of both establishments. Integration of these services, which has been total since 1978, has resulted in some economies in the staff and has functioned in a highly satisfactory manner since its inception. Integration of administrative services is considered the most appropriate organization option for sister establishments sharing the same physical facility.

Integrated, joint library services are provided to both establishments in a similar fashion with permanent library staff carried on the Great Lakes Forest Research Centre allocation. This, too, has resulted in some economies in both staff and library space and has the added advantage that library equipment and other facilities do not have to be duplicated.

As opportunities present themselves in the future, the desirability of further integration of common support services will be investigated thoroughly with the Great Lakes Forest Research Centre.

FP-97**ADMINISTRATION, FINANCIAL &
ENGINEERING SERVICES**

PROJECT LEADER

(GLFRC)

OBJECTIVES *To provide a system of financial control and accountability in accordance with statutory and regulatory requirements: to provide general administrative support services including material management, records management, office services, fleet management: to provide operations and maintenance of the physical plant in support of the Institute's R & D programs.*

ACHIEVEMENTS When FPML was formed in 1977, the decision was made to integrate Administrative Services in one administrative unit under the Great Lakes Forest Research Centre providing administrative, financial and engineering services to both establishments. Engineering Services were integrated in 1977 and the remainder of administrative and financial services followed as of 1 April, 1978. The integrated system has operated in an effective and efficient manner to date.

During 1982-83, administrative, financial and engineering services were provided efficiently and effectively. Highlights during this fiscal year included addition of a second word processor to the typing pool, negotiation of a gas chromatograph (GC) Mass Spectrophotometer purchase in excess of 150K, transfer of the old Institute aircraft to the Maritimes Forest Research Centre, conversion of an additional vehicle to propane, and negotiation of a new contract for cafeteria services which resulted in a major improvement in services provided. Conversion to the Automated Financial Management System (AFMAS) Financial Control System was initiated. Deficiencies in the FPML hangar were corrected, and the FPML greenhouse heating system was renovated.

PROJECTIONS

During 1983-84 a continuing high level of administrative, financial and engineering services will be provided to FPML; a furniture audit will be undertaken; a

capital equipment verification system will be instituted; the AFMAS financial control system will be placed in service and required modification to Institute research & working space will be made.

FP-94

LIBRARY SERVICES

PROJECT LEADER

S. Burt (GLFRC)

OBJECTIVES *To provide essential library services to researchers and managers at the Forest Pest Management Institute in the most economical, effective and efficient manner.*

ACHIEVEMENTS The joint library servicing both FPML and the Great Lakes Forest Research Centre has served both establishments well since its conception. By 1981-82 the library was providing approximately 425 periodicals and abstracting journals for staff, and had on its accession list about 8,000 reference texts. Periodical subscriptions were reviewed; those periodicals no longer required were dropped and titles related to work being undertaken by the Institute were added.

A computer terminal was obtained for the library in the first quarter of 1982-83. It has greatly increased the efficiency of literature searches, and to a significant degree, has been responsible for a 50% increase in interlibrary loan requests from staff. A subscription agency was contracted to maintain over 400 subscriptions received by the library (at an attractive cost). The workload reduction which resulted has allowed library staff to concentrate more of their efforts in library activities which are more productive.

PROJECTIONS During 1983-84 Library Services will continue responding in an effective manner to library service needs expressed by management and staff. As part of a general upgrading of Library Services, it is planned to expand computer terminal facilities to include on-line verification and processing of interlibrary loans and to complete a recataloging project commenced some years back.



APPENDICES



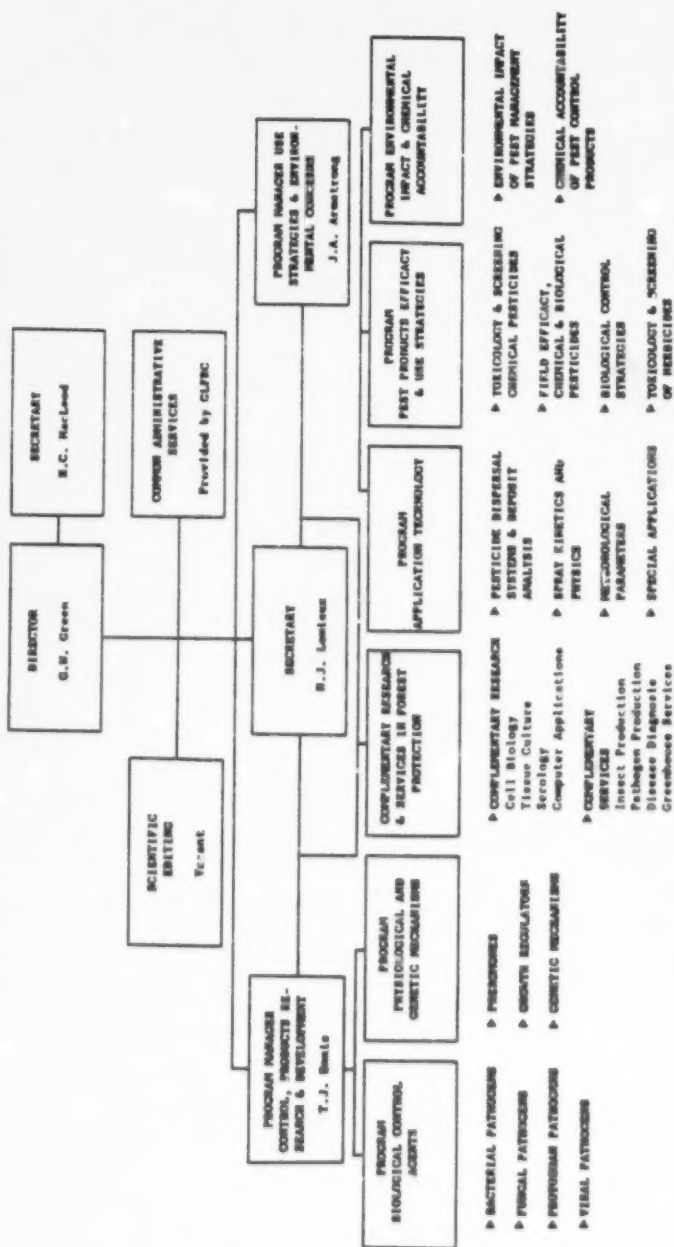
**FOREST PEST MANAGEMENT INSTITUTE
EXPENDITURES 1962-63
(9000)**

PROGRAM AREA	PERSON YEARS	SALARIES	OPERATIONS & MAINTENANCE	CAPITAL	TOTAL
Administration & Common Support					
Directorate	5	200.4	50.0	.1	250.5
Administration	-	-	211.1	35.9	247.0
Physical Plant	-	-	236.0	1.1	237.1
Info & Tech. Transfer	1	40.7	17.6	1.7	60.0
Library	-	-	58.5	1.7	60.2
Sub Total:	6	241.1	573.2	40.5	854.8
Improved Forest Management					
Biological Control	21	638.7	66.6	5.1	710.4
Chemical Control	18	511.3	73.3	19.5	604.1
Application Technology	6	76.3	28.0	10.3	114.6
Herbicides	4	144.2	2.6	1.2	148.0
Complementary					
Research & Services	21	585.2	67.6	4.3	657.1
Sub Total:	70	1 955.7	238.1	40.4	2 234.2
Environmental & Amenty Forestry					
Environmental Impact	7	178.3	26.9	15.9	221.1
Pesticide Accountability	4	121.3	33.2	141.3	295.8
Sub Total:	11	299.6	60.1	157.2	516.9
TOTAL:	87	2 496.4	871.4	238.1	3 605.9

**FOREST PEST MANAGEMENT INSTITUTE
RESEARCH & DEVELOPMENT CONTRACTS 1982-83**

CONTRACTOR	TITLE	AMOUNT	SCIENTIFIC AUTHORITY
K. Slessor Simon Fraser University	Synthesis of high purity standards for insect sex pheromones	8,840	G.G. Grant
Research & Productivity Council, Fredericton, N.B.	Chemicals attractive to the native elm bark beetle	3,000	FPML share of con- tract administered by GLFRC
A. Chung Queen's University	Studies on the mode of liberation of Nuclear Polyhedrosis Virus	5,714	J.C. Cunningham
P. Arntfjeld	Taxonomic evaluation of Dipteran insects from Icewater Creek	1,500	P.D. Kingsbury
A.T. Finnamore	Taxonomic evaluation of Hymenop- terous insects from Icewater Creek	1,500	P.D. Kingsbury
TOTAL		20,554	

FOREST PEST MANAGEMENT INSTITUTE - PROGRAM ORGANIZATION



FOREST PEST MANAGEMENT INSTITUTE ORGANIZATION & STAFF LISTING

(As of 31 March, 1983)

Director	Dr. G.W. Green Secretary: H.C. MacLeod
Program Managers	Dr. J.A. Armstrong Deputy Director Dr. T.J. Ennis Secretary: N.J. Lemieux
Administrative Officer	R.M. Dean Great Lakes Forest Research Centre
Scientific Editing	Vacant

RESEARCH & DEVELOPMENT PROJECTS

IMPROVED FOREST MANAGEMENT

BIOLOGICAL CONTROL RESEARCH

Program Manager: Dr. T.J. Ennis

<u>Project No.</u>	<u>Title</u>	<u>Scientific Staff</u>	<u>Technical Staff</u>
FP-1	Bacterial Pathogens	Dr. P.G. Fast (Project Leader)	R. Milne
FP-2	Fungal Pathogens	Dr. D. Tyrrell (Project Leader) Dr. D. Perry	K. Humphries M. Welton
FP-3	Protozoan Pathogens	Dr. G.G. Wilson (Project Leader)	E. Young
FP-4	Viral Pathogens	Dr. J.C. Cunningham (Project Leader) Dr. B.M. Arif Dr. W.J. Kaupp M. Legris	K. Brown R. Burke B. Cunningham

Program Manager: Dr. J.A. Armstrong

<u>Project No.</u>	<u>Title</u>	<u>Scientific Staff</u>	<u>Technical Staff</u>
FP-14	Biological Control Strategies	Vacant (Project Leader)	M.J. Hildebrand A. Moore

PHYSIOLOGICAL & GENETIC MECHANISMS

Program Manager: Dr. T.J. Ennis

FP-5	Insect Pheromones	Dr. G.G. Grant (Project Leader)	D. Frech L. MacDonald
FP-6	Insect Growth Regulators	Dr. A. Retnakaran (Project Leader)	L.F. Smith W. Tomkins
FP-7	Genetic Mechanisms	Dr. T.J. Ennis (Project in temporary abeyance)	

CHEMICAL CONTROL RESEARCH

Program Manager: Dr. J.A. Armstrong

FP-12	Toxicology	Dr. B.V. Helson (Project Leader)	D. Comba J. McFarlane
FP-13	Field Efficacy	B.L. Cadogan (Project Leader)	L. Pollock C. Nystrom B.F. Zylstra P. Ebling

APPLICATION TECHNOLOGY RESEARCH

Program Manager: Dr. J.A. Armstrong

FP-8	Dispersal Systems	Vacant (Project Leader)	A. Obarymskyj
FP-9	Spray Kinetics and Physics	Dr. A. Sundaram	J. Leung
FP-10	Meteorological Parameters	Dr. N. Payne (Project Leader)	J. Beveridge
FP-11	Special Applications	Dr. J. Turgeon (Project Leader)	N. Charlebois

HERBICIDES RESEARCH

Program Manager: Dr. J.A. Armstrong

<u>Project No.</u>	<u>Title</u>	<u>Scientific Staff</u>	<u>Technical Staff</u>
FP-19	Herbicides	Dr. P. Reynolds (Project Leader) Dr. R. Prasad	D. Travnick Vacant

ENVIRONMENTAL & AMENITY FORESTRY**ENVIRONMENTAL IMPACT & CHEMICAL ACCOUNTABILITY**

Program Manager: Dr. J.A. Armstrong

FP-15	Environmental Impact	P.D. Kingsbury (Project Leader) S. Holmes	D.P. Kreutzweiser B.B. McLeod R. Millikin K. Mortensen
FP-16	Chemical Accountability	Dr. K.M.S. Sundaram (Project Leader) J. Feng	C. Feng R. Nott

COMPLEMENTARY RESEARCH & SERVICES

Program Manager: Dr. T.J. Ennis

FP-17-1	Cell Biology	Dr. J. Percy (Study Leader)	J.A. MacDonald D. Pawlik
FP-17-2	Tissue Culture	Dr. S.S. Soni (Study Leader)	G. Caputo B. Cook
FP-17-3	Serology	Vacant (Study Leader)	B. Mathieson

Program Manager: Dr. J.A. Armstrong

FP-17-4	Computer Applications	Vacant (Study Leader)
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Program Manager: Dr. T.J. Ennis

<u>Project No.</u>	<u>Title</u>	<u>Scientific Staff</u>	<u>Technical Staff</u>
FP-18-1	Insect Production	D. Gridale (Study Leader)	K. Barratt W. Bodley C. Budau L. Harwood A. McMorran P. Naphan
FP-18-2	Pathogen Production	J. McPhee (Study Leader)	H. Wigney
FP-18-3	Disease Diagnosis	Vacant (Study Leader)	
FP-18-4	Greenhouse Services	D. Buckley (Study Leader)	N. Lautenslager

PUBLICATIONS 1982-83

The following list of publications includes only those papers published or issued during the 1982-83 fiscal year (April 1, 1982 - March 31, 1983). The material listed here includes only journal articles, book chapters, papers appearing in Proceedings, Abstract Papers, and Information Reports. Many other reports of an internal or special nature were written, but because they are not intended for general circulation, they are not listed here.

PUBLICATIONS

- Burke, J., Percy, J. 1982. Survey of pathogens in the large aspen tortrix, *Choristoneura conflictana* (Lepidoptera: Tortricidae) in Ontario and British Columbia with particular reference to granulosis virus. Can. Entomol. 114:457-459.
- Burke, J. & Percy, J. 1983. Viruses infecting five species of Lepidoptera. Canadian Forestry Service Research Notes 3(1):1-2.
- Cadogan, B.L.; Laing, J.E. 1981. A study of *Balaustrium putmani* in apple orchards in southern Ontario. Proc. Entomol. Soc. Ont. 112:13-22.
- Cunningham, J.C. 1982. Field trials with baculovirus: control of forest insect pests. Pages 335-386. In E. Kurstak, ed. Microbial and Viral Pesticides. Marcel Dekker, Inc., New York.
- Drummond, R.L.; Cadogan, B.L.; Wilson, M. 1981. Ticks on livestock in Barbados, West Indies. J. Vet. Parasite 8(3):253-260.
- Fast, P.G. 1982. *Bacillus thuringiensis* parasporal toxin: Aspects of the chemistry and mode of action. Toxicon 20 (suppl. 1):18.
- Gole, J.W.D.; Downer, R.G.H.; Sohi, S.S. 1982. Octopamine-sensitive adenylate cyclase in hemocytes of the forest tent caterpillar, *Malacosoma disstria* (Lepidoptera: Lasiocampidae). Can. J. Zool. 0:825-829.
- Grant, G.G. 1983. Sex pheromone of the maple leaf roller, *Cenopsis acerivorana* (Lepidoptera: Tortricidae). Can. Entomol. 115:189-194.

- Holmes, S.B.; Kingsbury, P.D. 1982. Comparative effects of three Matacil field formulations on stream benthos and fish. Can. For. Serv., For. Pest. Manage. Inst. Inf. Rept. FPM-X-55, 51 pp.
- Kaupp, W.J. 1982. A paper cup container for the bioassay of nuclear polyhedrosis virus on foliage. Canadian Forestry Service Research Notes 2(4):23.
- Kreutzweiser, D.P. 1982. The effects of permethrin on the invertebrate fauna of a Quebec forest. Can. For. Serv., For. Pest. Manage. Inst. Inf. Rept. FPM-X-50, 83 pp.
- Kreutzweiser, D.P.; Kingsbury, P.D. 1982. Recovery of stream benthos and its utilization by native fish following high dosage permethrin applications. Can. For. Serv., For. Pest Manage. Inst. Inf. Rept. FPM-X-59, 22 pp. plus 23 Appendix Tables.
- McLeod, B.B.; Millikin, R.L. 1982. Environmental impact assessment of experimental spruce budworm adulticide trials: effects on forest avifauna. Can. For. Serv., For. Pest Manage. Inst. Inf. Rept. FPM-X-54, 109 pp.
- Morris, O.N. 1982. Bacteria as pesticides: forest applications. pp. 239-287. In E. Kurstak, ed. Microbial and viral pesticides. Marcel Dekker, New York.
- Percy, J.; Wilson, G.; Burke, J. 1982. Development and ultrastructure of a microsporidian parasite in the midgut cells of the larch sawfly, *Pristiphora erichsonii* (Hymenoptera: Tenthredinidae). J. Invert. Pathol. 39:49-59.
- Perry, D.F.; Latge, J.P. 1982. Dormancy and germination in *Conidiobolus obscurus* azygospores. Trans. Brit. Mycol. Soc. 78(2):221-225.
- Randall, A.P. 1982. Equipment and technique for rapid determination of second-instar larval counts from branch samples. Canadian Forestry Service Research Notes 2(2):9-12.
- Retnakaran, A. 1982. Do regulatory agencies unwittingly favour toxic pesticides? Bull. Entomol. Soc. Amer. 28:146.

- Retnakaran, A. 1982. Laboratory and field evaluation of a fast-acting insect growth regulator against the spruce budworm. *Can. Entomol.* 114:523-530.
- Retnakaran, A., Grant, G.G., Ennis, T.J., East, P.G., Arif, B.M., Tyrrell, D., Wilson, G.G. 1983. Development of environmentally acceptable methods for controlling insect pests of forests. *Can. For. Serv., For. Pest Manage. Inst. Int. Rept. FPM-X-82*, 22 pp.
- Retnakaran, A., Smith, L. 1982. Reproductive effects of insect growth regulators on the white pine weevil. *Can. Entomol.* 114:361-363.
- Retnakaran, A., Tomkins, W. 1982. Effectiveness of growth-inhibiting insect growth regulators in controlling the oak leaf shredder. *Canadian Forest Service Research Notes* 2(1):5-6.
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- Sohi, S.S.; Ennis, T.J. 1981. Chromosomal characterization of *Neodiprion lecontei* (Hymenoptera: Diprionidae) cell lines. *Proc. Entomol. Soc. Ont.* 112:45-48.
- Sundaram, A. 1982. Foliar impaction and distribution of aerially sprayed encapsulated droplets. *Ann. Summer Meeting Amer. Soc. Agric. Eng. Paper No. 82-1006*, 27 pp.
- Sundaram, A.; Sundaram, K.M.S. 1982. Influence of formulation properties on spray droplet spectrum, deposition and persistence of fenitrothion following a simulated aerial application. *Fifth Int'l. Cong. Pest. Chem. Abs. Papers* 3:VIII 5-6.
- Sundaram, A.; Sundaram, K.M.S., Gadogan, B.L. 1982. Effects of formulations and weather factors on foliar and ground deposition of aminocarb aerial sprays. *XIV Ann. East. Can. Workshop Pest. Res. and Env. Pollutants Abs. Papers* 14:9.
- Sundaram, K.M.S. 1982. Distribution, persistence and fate of fenitrothion insecticide in a conifer forest ecosystem following its aerial application for five consecutive years. *Fifth Int'l. Cong. Pest. Chem. Abs. Papers* 3:VI, e-7.

- Sundaram, K.M.S. 1982. Fate of Matacil 180F in aquatic environment. East. Can. Pest. Conf. Abs. Papers, p. 147.
- Sundaram, K.M.S. 1982. Influence of additives on spray formulations. Can. Pest. Manage. Soc. Abs. Papers 21:11.
- Sundaram, K.M.S., Feng, J., Feng, C., Nott, R., Aubertin, V. 1982. *In vitro* and *in vivo* study on the brain AChE inhibition of brook trout by aminocarb and its metabolite. IX Ann. AG. Toxic Workshop Abs. Papers 9:3.
- Sundaram, K.M.S., Sundaram, A. 1982. Influence of formulation on droplet size, deposit concentration and persistence of fenitrothion in conifers following a simulated aerial application. Canadian Forestry Service Research Notes 2(1):2-5.
- Szeto, S.; Sundaram, K.M.S. 1982. The behaviour and degradation of Chlorpyrifos-methyl in two aquatic models. J. Agric. Food Chem. 30:1032-1035.
- Tyrrell, D.; Welton, M.A. 1983. Isolation and culture of *Massospora larvispora*. Canadian Forestry Service Research Notes 3(1):1.
- Wilson, G.G. 1982. Preliminary observations of life stages of a microsporidian parasite in the white pine weevil, *Pissodes strobi*. J. Protozool. 28:484.
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- Wilson, G.G. 1982. Transmission of *Nosema fumiferanae* (Microsporidia) to its host *Choristoneura fumiferana* (Clem.). Z. Parasitenkd. 68:47-51.
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